



New Aura Microwave Limb Sounder observations of BrO and implications for Br_y

L. Millán¹, N. Livesey¹, W. Read¹, L. Froidevaux¹, D. Kinnison², R. Harwood³, I. A. MacKenzie³ and M. P. Chipperfield⁴

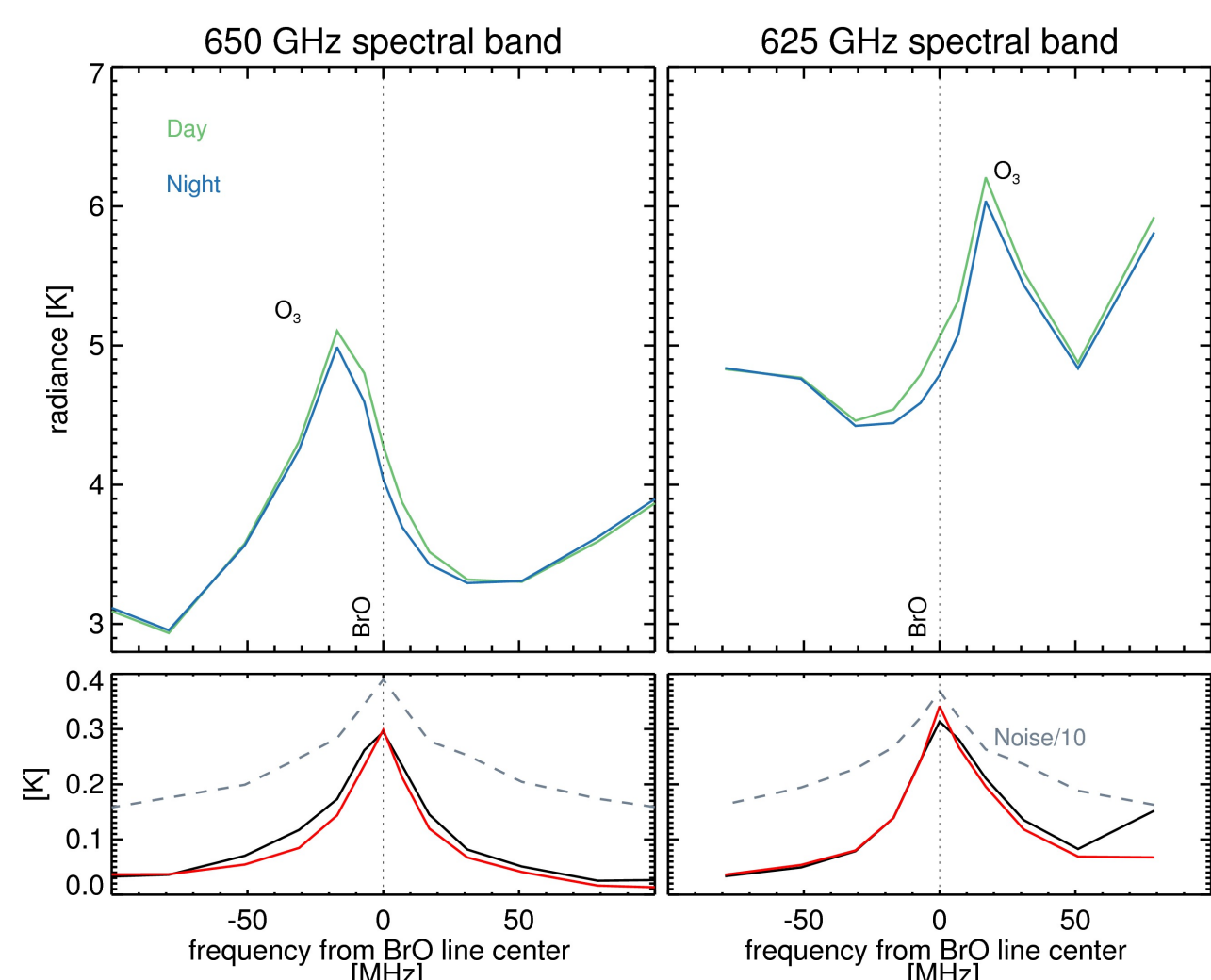
Introduction

- Stratospheric O₃ has been a great concern since 1985 when the now famous O₃ hole was reported.
- In the stratosphere, O₃ depletion is caused by complex chemical processes involving radicals containing chlorine and bromine.

MLS BrO Observations

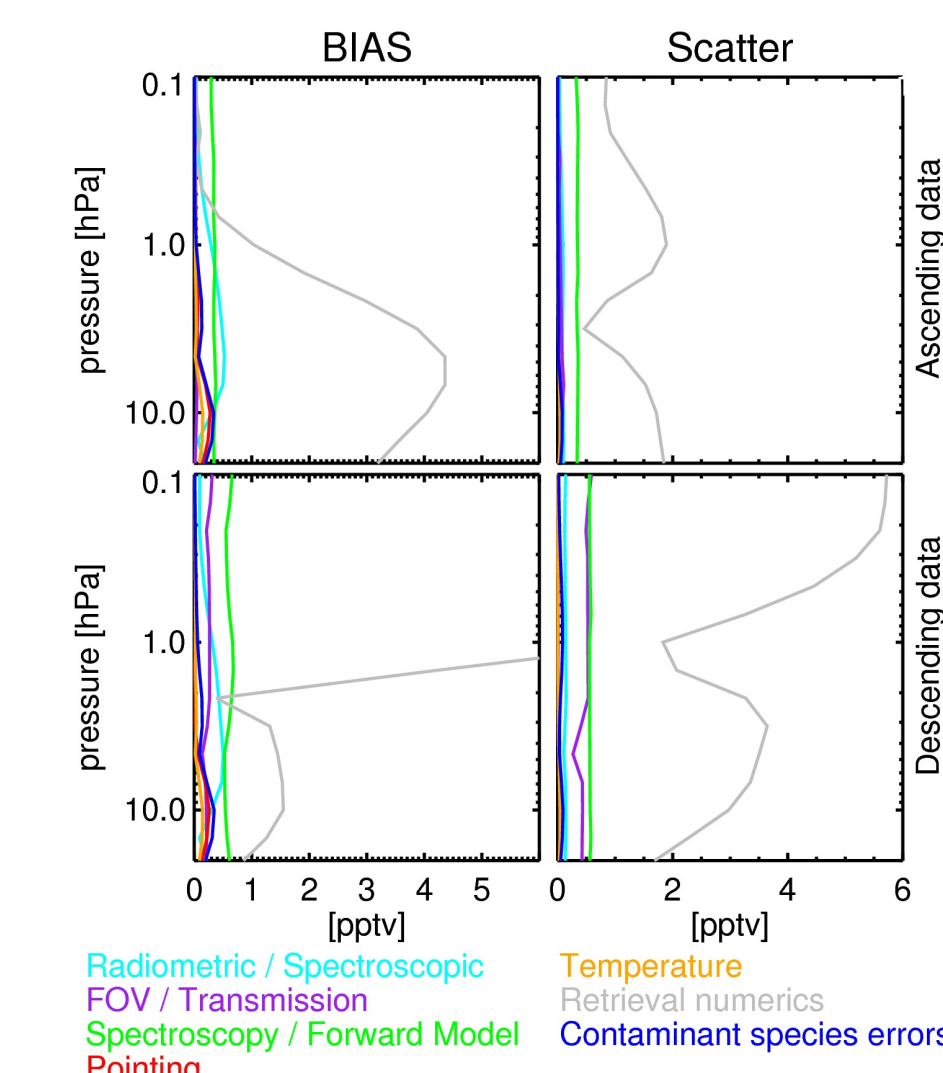
- MLS observes two sets of BrO emission lines. In both cases the ~0.2K BrO signal overlaps with a ~2K O₃ signal.
- Taking the ascending-descending (day-night) difference removes the O₃ signal, which does not have a diurnal variation at these altitudes, revealing the strongly diurnal nature of BrO.
- The ~0.2K BrO signal is well below the individual measurement precision of about 4K, hence, significant averaging is required.

Top: Average MLS radiance from 55S and 55N and for limb tangents from 10 to 4.6 hPa for 2005.
Bottom: differences between the ascending and descending measurements (black). The red lines represent the spectrum simulated using the new averaged BrO retrieved value introduced here. The dashed gray line is 1/10 of the expected single scan noise.



Precision and systematic errors

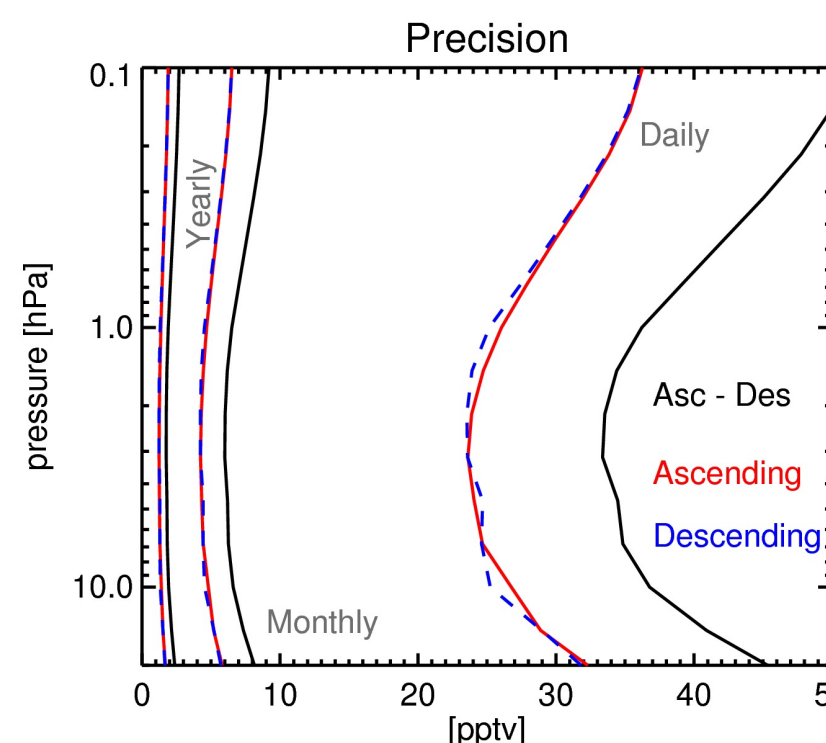
Expected precision for a daily, monthly and yearly 10° latitude bin. The “Asc-Des” precision is the root sum square of the ascending and descending values.



Estimated impact of various families of systematic errors for ascending-descending MLS OL2 BrO observations.

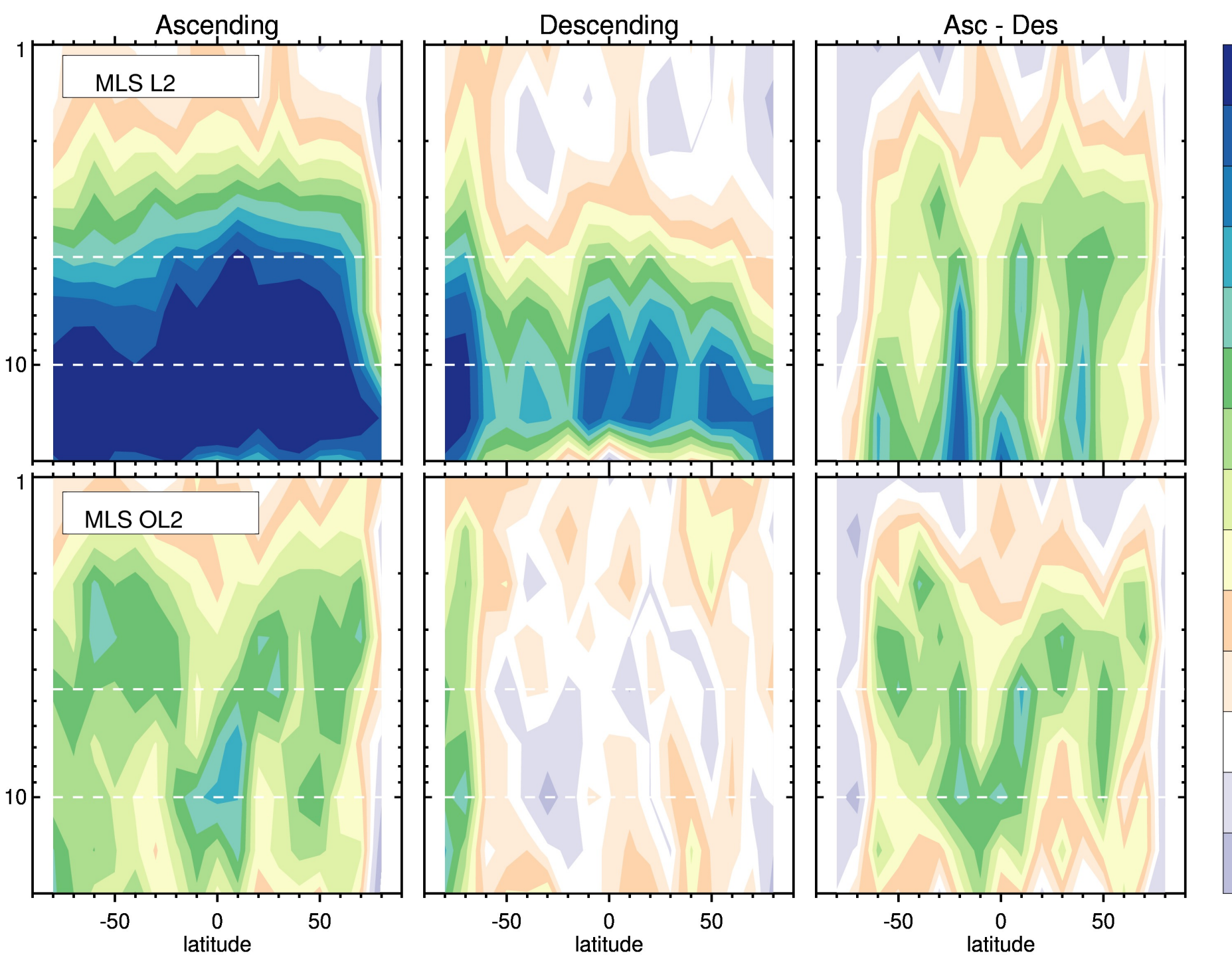
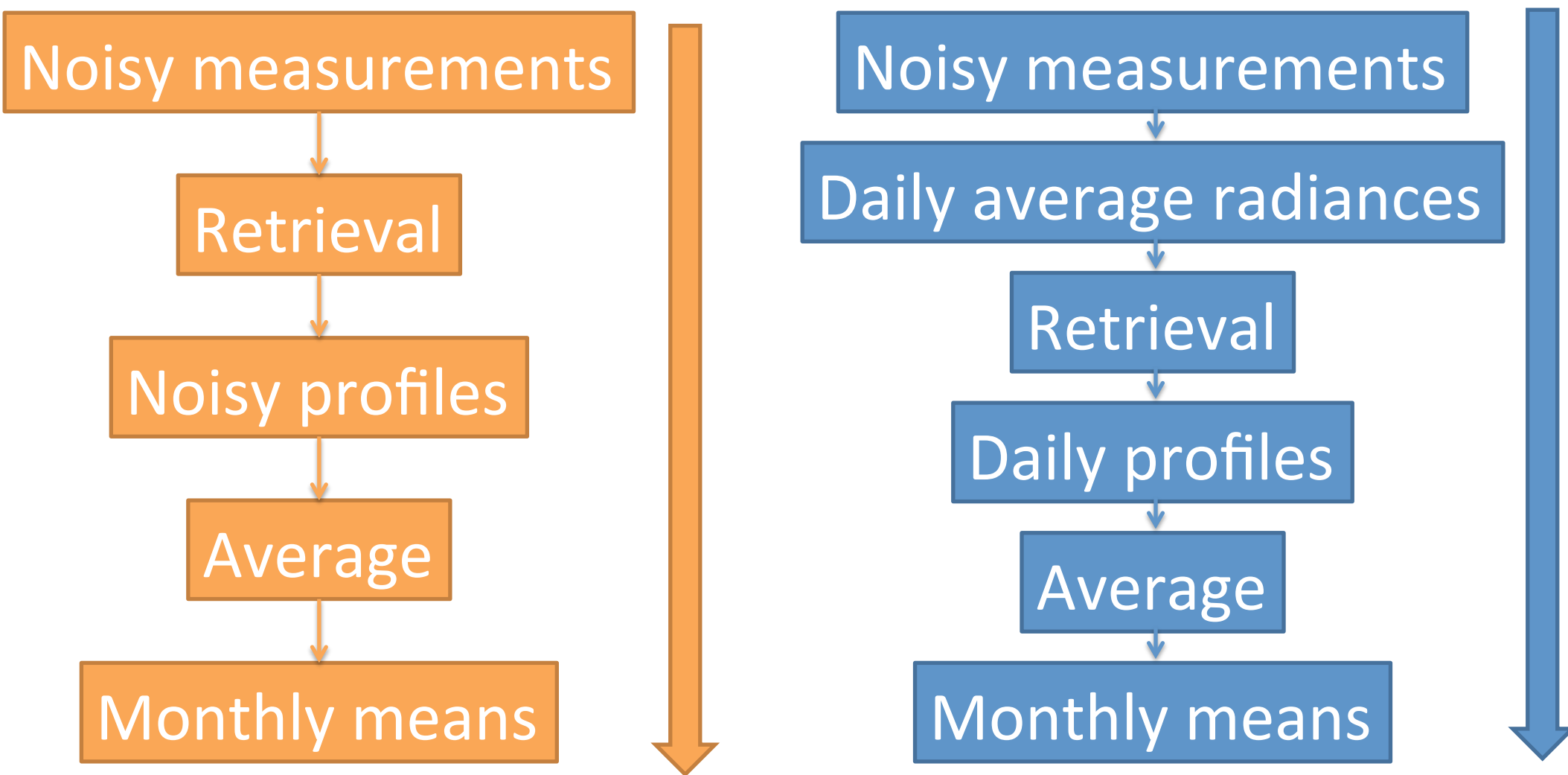
The left panel shows the possible biases and the right panel shows the additional scatter introduced by each family of systematic errors.

The black lines are the root sum squares of all the biases or the scatters shown.



Retrieval Methodology

- To date, two different approaches to do the required averaging and inversion has been implemented.
- The **standard production** approach (MLS L2) and the **offline** (MLS OL2).



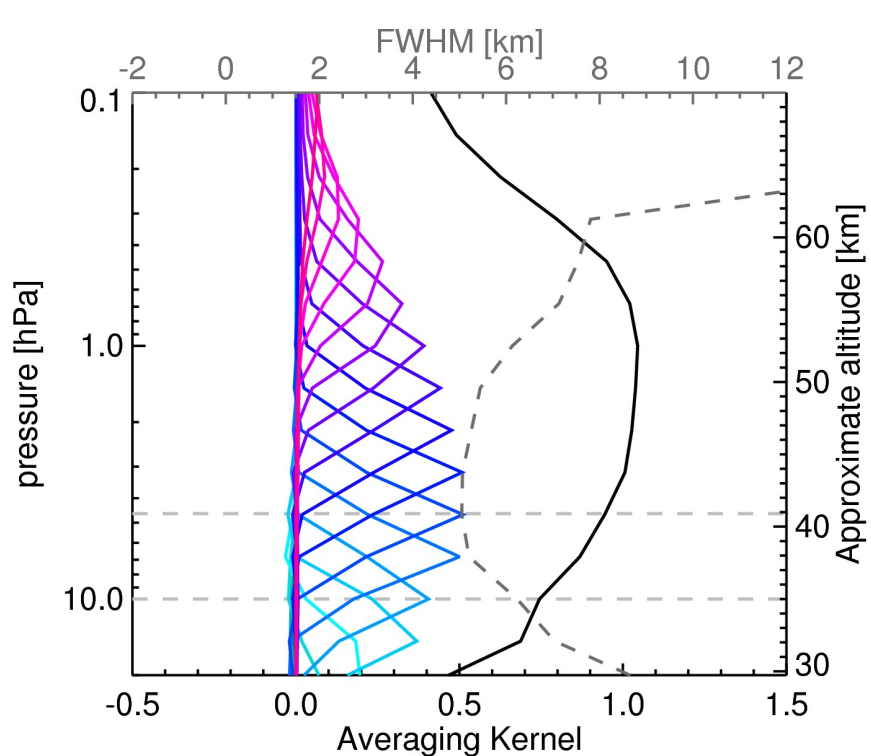
Monthly zonal mean for January 2005 of MLS BrO observations for ascending (mainly daytime) and descending (mainly nighttime) phases of the orbit.

To reduce the impact of systematic errors, the ascending-descending BrO difference need to be used as an estimate of the daytime BrO.

The region between the white dashed lines indicates where the MLS ascending-descending difference are suitable for scientific use. This region is a compromise between the influence of the *a priori* and the systematic errors.

This restricts the usable data to between 50S to 50N.

Vertical resolution



Averaging kernels for the retrieval of BrO mixing ratio at the equator (those at other latitudes are very similar).

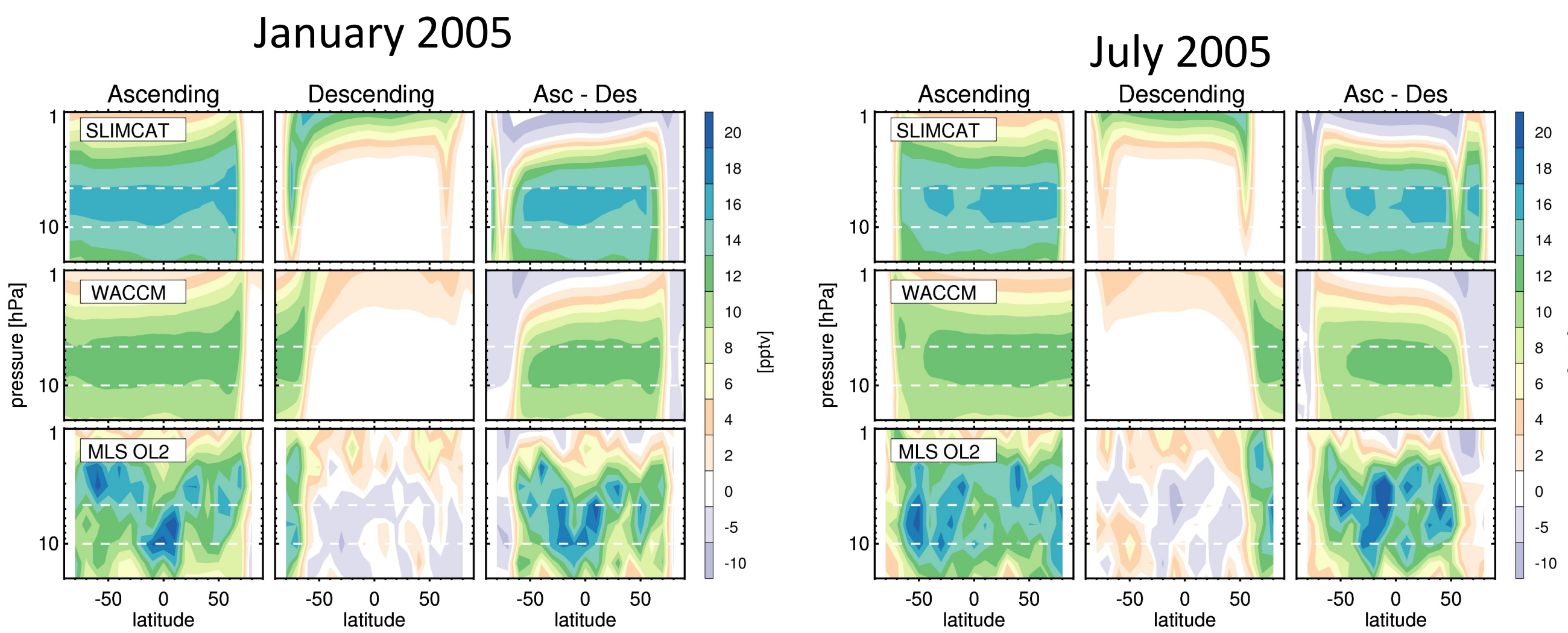
The black line is the integrated area under each kernel: values near unity indicate that most information was provided by the measurements while lower values indicate that the retrieval was influenced by the *a priori*.

The dashed gray line is a measure of the vertical resolution of the retrieved profile (derived from the full width at half maximum (FWHM) of the averaging kernels approximately scaled into kilometers).

Comparisons with numerical models

Monthly zonal mean of MLS BrO observations for ascending and descending phases of the orbits as well as the SLIMCAT and WACCM models .

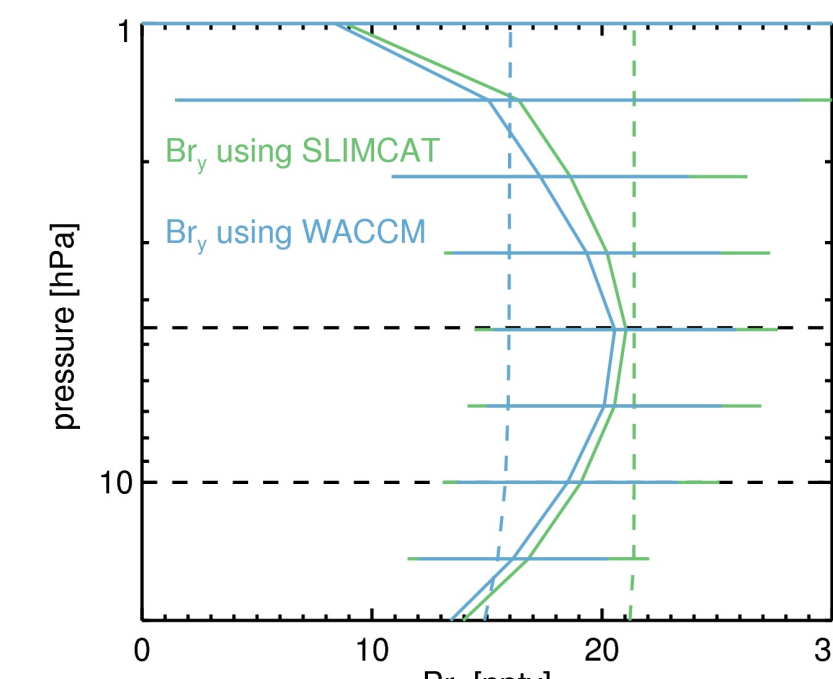
MLS OL2 data display the distinct BrO ~10 hPa diurnal variation not only at mid and equatorial latitudes but also at the poles with negligible BrO abundances around the polar winter regions (where there is constant nighttime) and higher BrO values in the polar summer regions (where there is constant daytime).



Implications for Br_y

- From MLS BrO measurements, Br_y can be inferred approximately from chemical models using the expression:

$$Br_y^{MLS} = BrO^{MLS} \left(\frac{Br_y^{MODEL}}{BrO^{MODEL}} \right)$$



2005 average Br_y inferred from MLS data using the SLIMCAT (green) and the WACCM (blue) models.

The dashed lines show the SLIMCAT (green) and WACCM (blue) modeled values.

With an estimate of the age of this air (using N₂O) and with an estimate of the Br_y sources (Montzka et al 2003), we estimate a 5 ± 4.5 VLS contribution to Br_y.

Estimates of Br_y from VLS (Br_y^{VLS}) from BrO measurements as discussed in chapter 1 of WMO (2010) as well as the estimate from this study.

As shown, the new MLS estimate of VLS contribution to Br_y agrees within the respective uncertainties with all the previous estimates.

